ELECTRONICALLY COMMUTATED MOTOR AND

METHOD FOR CONTROLLING THE SAME

The invention relates to an electronically commutated motor and to a method for controlling an electronically commutated motor.

With such motors, the occurrence of commutation noise is problematic for a number of applications. A number of suggested solutions to this are known from the existing art. A characteristic common to all the suggested solutions is that they are very complex and cost-intensive.

It is the object of the present invention to reduce commutation noise. This object is achieved by a motor according to claim 1 and a method according to claim 6.

The invention is based on the recognition that low-noise commutation can be achieved by means of a current through the stator winding that is substantially constant at least during the on-time of the stator winding. A basic idea of the invention is therefore to influence the working range of the field-effect transistor associated with the stator winding in such a way that the transistor generates, during the respective energization, a substantially constant current through the stator winding. A component implemented for the purpose is provided therefor.

According to a preferred embodiment of the invention, the component is implemented in such a way that the field-effect transistor is operated as a pinch-off current source.

In a further preferred embodiment of the invention, the component comprises a transistor. In other words, the field-effect transistor associated with the stator winding is shifted into the pinch-off region with the aid of a further transistor. This further transistor is preferably controlled by means of a variable resistor or by means of a microcontroller. This control action results in a change in the conductivity of the transistor, which results in a displacement of the working point into the desired region. The control action on the transistor modifies the current intensity through the stator winding, and thus the rotation speed of the motor.

In a further embodiment of the invention, provision is made to continuously keep the current in the stator winding substantially constant during operation of the motor.

As compared with known suggested solutions, the present invention enables low-noise commutation with a comparatively small outlay of material, and using a comparatively simple circuit. The invention is not limited to a specific type of motor.

Further details and advantageous refinements of the invention are evident from the exemplifying embodiments described below and depicted in the drawings, in which:

FIG. 1 is a greatly simplified circuit diagram of an electronically commutated motor according to a first embodiment of the invention;

FIG. 2 is a greatly simplified circuit diagram of an electronically commutated motor according to a second embodiment of the invention;

FIG. 3 schematically depicts the commutation current through a stator winding according to the existing art (curve A) and according to embodiments of the invention (curves B and C);

FIG. 4 is a greatly simplified circuit diagram of an electronically commutated motor according to a third embodiment of the invention; and

FIG. 5 shows a family of characteristic curves of an n-channel field-effect transistor.

FIG. 1 is an exemplary depiction of a two-phase electric
motor that can be used with the present invention. The
electronically commutated DC motor 10 comprises two stator
winding phases 12, 14 and a permanent-magnet rotor 16
(depicted merely symbolically). Arranged in the vicinity of
rotor 16 is a Hall sensor 18. For reasons of clarity, the
latter is illustrated at a different location in the present
circuit diagram. Phase 12 is in series with a first power-
stage transistor 20 (MOSFET), and phase 14 is in series with a
second power-stage transistor 22 (MOSFET). Phases 12, 14 are
connected to a positive lead 24. Positive lead 24 and negative
lead 26 are connected, during operation, to a power supply
(not depicted) or to a battery. Phases 12, 14 are usually
coupled to one another in transformer fashion via the iron of
the stator lamination stack.

Hall sensor 18 is connected on the one hand via a
resistor 28 to positive lead 24, and on the other hand to
negative lead 26. The output signal of Hall sensor 18 is
delivered, through resistors 30, 32 and a capacitor 34, to the
two inputs IN1 and IN2 of a microcontroller (μC) 36. μC 36 is
connected at its terminal VCC to positive lead 24, and at its
terminal GND to negative lead 26. A storage capacitor 38 is
arranged between positive lead 24 and negative lead 26. μC 36
generates signals OUT1 and OUT2 to control power-stage
transistors 20, 22, and at the same time provides stalling
protection for motor 10. The control signals are generated by
means of a program routine or control routine executing in μC
36. Signal OUT1 is delivered through a resistor 40 to the gate
of power-stage transistor 20. In the same fashion, signal OUT2
is delivered through a resistor 42 to the gate of power-stage
transistor 22. The gate of power-stage transistor 20 is
connected via a resistor 44 to negative lead 26.

In the same fashion, the gate of power-stage transistor 22 is connected via a resistor 46 to negative lead 26.

Source terminals S of power-stage transistors 20, 22 are connected via a control transistor 48 (MOSFET) to negative lead 26. Gate G of control transistor 48 is connected to a variable resistor 50 that is arranged between positive lead 24 and negative lead 26. According to the present invention, power-stage transistors 20, 22 are respectively controlled in the source region by control transistor 48 in such a way that the current through stator windings 12, 14 is substantially constant at least during commutation. For that purpose, power-stage transistors 20, 22 are operated as a pinch-off current source (cf. Tietze/Schenk, Halbleiter-Schaltungstechnik [Semiconductor circuit engineering], 12th ed., pp. 411 ff.).

For example, when power-stage transistor 20 is controlled by control signal OUT1, control transistor 48 acts as a resistance with respect to ground. In this embodiment of the invention, the current intensity through stator windings 12, 14, and thus the rotation speed of motor 10, can be adjusted by means of variable resistor 50 at the gate of control transistor 48. This embodiment is especially suitable for those applications in which a change in motor rotation speed during operation is not necessary.

FIG. 5 shows a family of output characteristic curves of an n-channel field-effect transistor, which family has four characteristic curves 311, 312, 313, and 314. The drain current I_D is plotted for four different gate-source voltages U_{GS} = 2.5 V, 3.0 V, 3.5 V, and 4.0 V as a function of drain-source voltage U_{DS}. The family of characteristic curves displays an ohmic region (triode region) OB 300 in which characteristic curves 311 to 314 extend, at the origin U_{DS} = 0 V, almost linearly through the origin, yielding a behavior similar to that of an ohmic resistor.

In addition to ohmic region OB 300, there is a so-called pinch-off region AB 302 in which characteristic curves 311 to 314 exhibit an almost constant drain current I_D. A line 301 marks the boundary between ohmic region OB 300 and pinch-off region AB 302.

What is achieved by way of control transistor 48 of FIG. 1 is that drain-source voltage U_{DS} is modified, and the magnitude of the current (i) through stator winding 12 is thus also influenced. Because boundary 301 between ohmic region OB 300 and pinch-off region AB 302 is likewise dependent on drain-source voltage U_{DS}, what is also achieved, if applicable, is that transistors 20, 22 operate in the pinch-off region.

All types of field-effect transistors exhibit a pinch-off region of this kind.

FIG. 2 is the circuit diagram of a motor 10 according to the present invention in a second embodiment, in which the motor rotation speed can be controlled without difficulty.

For this variable control function, gate G of control transistor 48 is connected to output OUT 3 of a μC 36 via a low-pass filter constituted by a resistor 52 and a capacitor 54. The low-pass filter converts the digital control signals 51 of μC 36 into an analog voltage signal whose magnitude is dependent on the pulse duty factor of control signals 51. The remainder of the circuit arrangement corresponds to that of FIG. 1. Appropriate control applied to control transistor 48 ensures that the current through stator windings 12, 14 is substantially constant. Modification of the conductivity of control transistor 48, and thus a modification of the motor rotation speed, are accomplished in accordance with the program routines or control routines executing in μC 36.

When control transistor 48 is controlled in such a way that it exhibits a high resistance and thus poor conductivity, the potential at the source of the respective power-stage transistor 20, 22 rises. Less current flows through power-stage transistor 20, 22, and it transitions into the pinch-off region.

When power transistor 48 is controlled in such a way that it exhibits a low resistance and thus high conductivity, the potential present at the source of the respective power-stage transistor 20, 22 is low. The high gate-source voltage associated therewith results in a correspondingly high current intensity in stator winding 12, 14.

As depicted in FIG. 3, a smoothing of the current curve is achieved with the present invention. In contrast to conventional commutation methods (curve A), according to the present invention the current through a stator winding is kept substantially constant either during energization (curve B) or throughout the entire operating period of the motor (curve C).

FIG. 4 shows an exemplifying embodiment according to the present invention of a full-bridge circuit for a three-phase electronically commutated motor 10'.

Identical or identically functioning components are labeled with the same reference characters and will not be explained again.

Stator 220 comprises three winding phases 221, 222, 223 in a wye configuration, which are connected between a neutral point 224 and winding terminals L1, L2, and L3.

Power stage 200 is implemented as a full bridge, and comprises three upper transistors 201, 202, 203 that are connected between positive lead 24 and respective winding terminals L1, L2, and L3; as well as three lower transistors 204, 205, 206 that are connected between respective winding terminals L1, L2, and L3 and control transistor 48.

Gate terminals G of power-stage transistors 201 to 206 are controlled by a power-stage control system 210 via terminals 211 to 216.

Control transistor 48 is adjusted in such a way that lower transistors 204, 205, 206 each operate in the pinch-off region.

Commutation is accomplished by means of control input to power-stage transistors 211 to 216, and therefore to winding terminals L1, L2, L3, as a function of the position of rotor 16'.

In a preferred embodiment, the respective upper transistors 201, 202, 203 or lower transistors 204, 205, 206 are made conductive for the entire commutation period. In a further preferred embodiment, commutation off-times are provided upon a change in energization in order to prevent short-circuiting. It is additionally possible to control upper transistors 201, 202, 203 using a clock-timed control signal 201, 202, 203.

Numerous variants and modifications are of course possible within the scope of the present invention.